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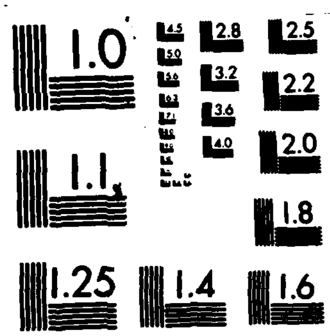

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Report of the

DOD-UNIVERSITY FORUM WORKING GROUP on Engineering and Science Education

July 1983

Office of the Under Secretary of Defense
for Research and Engineering
Washington, D.C. 20301

REPORT OF THE
DOD - UNIVERSITY FORUM WORKING GROUP
ON
ENGINEERING AND SCIENCE EDUCATION

July 1983

Co-Chairmen

Dr. Robert C. Seamans, Jr.
Henry R. Luce Professor
of Environment and
Public Policy
Massachusetts Institute
of Technology

Dr. Lawrence J. Korb
Assistant Secretary of
Defense for Manpower,
Reserve Affairs and
Logistics

August 18, 1983

Dr. Richard D. DeLauer
Under Secretary of Defense
for Research and Engineering
The Pentagon
Washington, D. C. 20301

Dear Dr. DeLauer:

We are pleased to transmit to you the final report of the DOD-University Forum Working Group on Engineering and Science Education. The preparation of this report was a highly collaborative effort, and we wish to recognize the Department of Defense and university members of the Working Group, as well as those supporting staff members identified in Appendix C, who made this report possible. We believe that the report responds to the Forum's tasking to examine DoD's needs for trained technical personnel in light of the present deteriorated capability of our nation's universities to produce well-qualified engineers and scientists.

In presenting our findings and recommendations to you and the DoD University Forum, we especially wish to draw your attention to the heightened Congressional interest in engineering and science education. Our recommendations on university facilities, instrumentation and graduate fellowships are, in fact, supported by recent House and Senate Armed Services Committee reports requesting DoD to undertake specific actions in these areas. Due to this growing national support for strengthening engineering and science education, and due to the potential adverse impact that deficiencies in engineering and science education could have on national defense, we believe that it is appropriate for DoD to assume a leadership role in solving this problem.

In this regard, we were encouraged to find that the Office of the Secretary of Defense and the Military Departments have initiated several programs to strengthen engineering and science education. These span the precollege, undergraduate and graduate levels and include opportunities for both civilian and military personnel. Since these efforts represent a good, albeit limited, beginning, we have recommended that they be considerably strengthened, and that additional initiatives also be undertaken.

To accomplish these new initiatives and to strengthen and coordinate the DoD programs now underway, we believe that it is essential to establish a focal point for engineering and science education within the Office of the Secretary of Defense to provide the leadership, policy guidance and thrust necessary to carrying out these recommendations. We see the creation of this focal point as the primary step to be taken in acting on the recommendations of our report.

We appreciate the opportunity you have provided us to examine this important issue. We look forward to hearing your reactions to the report.

Sincerely,

Robert C. Seamans, Jr.
Henry R. Luce Professor of Environment and Public Policy
Massachusetts Institute of Technology
Cambridge, Massachusetts

Lawrence J. Korb
Assistant Secretary of Defense for Manpower, Reserve Affairs and Logistics
The Pentagon
Washington, D. C.

Copy to Dr. Donald Kennedy

Long-term U.S. economic growth requires better use of R&D resources and closer interaction of the academic, government, and industrial research communities. The federal government has proposed to increase support for university research as a key means of addressing national needs for new knowledge in fields important to industrial development and for training of technical personnel. But continuing growth in support for basic research depends on how well the science community can agree on what research investments will have the greatest impact in producing new knowledge. . . . ~~So,~~ very early in ~~our discussions,~~ The President assigned high priority to strengthening our national base of scientific and technical personnel. That included immediate emphasis on training people in the areas of science and technology that were likely to have the greatest impact on both industrial growth and national defense. p. V

Dr. George A. Keyworth, II
President's Science Advisor
Director of the White House
Office of Science and Technology
Policy, 24 March 1983, in
Science, Vol. 220, pp. 1122-3

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HIGHLIGHTS

The Forum charged the Working Group to:

- Review DOD needs for S&E manpower and assess DOD S&E education initiatives.

- Examine the deteriorated environment in university S&E departments and assess the effectiveness of DOD efforts to resolve these issues.

- Identify key leverage points where appropriate action could be applied by DOD.

- Assess further DOD support initiatives for S&E education, including one modeled after the prepaid G.I. bill.

Findings

- For the past 10 years Defense has been losing a substantial number of mid-career S&E personnel from DOD laboratories as well as the military.

- Shortages of civilian and military S&E personnel are reasonably well documented; however, qualitative aspects of the problem are not well defined or understood.

- Forecasts by NSF project shortages in the national pool of engineering and technical personnel by 1987 if current trends persist.

- DOD is not taking full advantage of legislative authorization enabling personnel to pursue continuing education opportunities.

- Computer occupations are not adequately reflected either in civilian or military job classifications.

- Work-related training programs for undergraduates are proving to be effective recruitment and retention tools.

- ROTC scholarships are drawing high-caliber S&E officers.

- The quantity of new Defense civilian S&E hires is sufficient, but their quality does not appear to be as good as ROTC.

- The Air Force bonus program for S&E officers is having desired retention results.

- The Army, Navy and Air Force have each initiated fellowship and assistantship programs in Defense related disciplines; program sizes are small but their focus is on quality.

- DOD began a University Research Instrumentation Program in 1983.

- A Summer Faculty Program provides university faculty with research experience at DOD laboratories.

- Deficiencies in research facilities and equipment are acute in most universities.

- Pay differentials are pulling high-caliber graduate students and junior faculty into industry.

- Engineering Ph.D. programs are having difficulty in attracting an adequate number of students with U.S. citizenship.

- The precollege math and science foundation has eroded; there is an acute shortage of high school math and science teachers, the quality of education in these subjects has dropped and the number of high school students enrolling in rigorous math and science courses has declined.

Recommendations

1. Continue existing policies supporting real growth (at 7% per year) in university research.

2. Assess current qualitative aspects of the DOD S&E workforce.

3. Establish a focal point for S&E education in OSD.

4. Strengthen military undergraduate and graduate level S&E education programs.

5. Strengthen civilian precollege, undergraduate and graduate level assistance programs, including creation of a new graduate education program for civilians.

6. Increase opportunities for continuing education among DOD civilian S&E's.

7. Increase interchanges between senior government S&E's and colleagues in industry and academia.

8. Expand DOD graduate fellowship programs to $18 million per year, without altering emphasis on quality.

9. Establish a comprehensive Faculty Development Program.

10. Encourage development of university programs in Defense related technologies.

11. Expand DOD-University Research Instrumentation Program to the level of $100 million per year for at least 5 years; request new appropriations for this effort.

12. Request new appropriations for and establish a University Research Facilities Rehabilitation Program (at $100 million per year for 10 years) targeted on fields of interest to DOD; encourage other agencies to do the same.

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EXECUTIVE SUMMARY

In recent years, the nation's security has become increasingly dependent upon maintaining U.S. superiority in broad areas of science and technology; however, this superiority is now being challenged as never before.

Our ability to meet this challenge will depend in large measure on the quality of the engineering and scientific workforce that will make the technological advances of the future.

The needs of the Department of Defense for trained technical personnel, and the current capabilities of the university community for producing an adequate supply of qualified engineers and scientists, is the subject of this report of the DOD-University Forum Working Group on Engineering and Science Education.

Project Tasking

The DOD-University Forum, co-chaired by Dr. Richard DeLauer, Under Secretary of Defense for Research and Engineering, and Dr. Donald Kennedy, President of Stanford University, established the Working Group on Engineering and Science Education in February 1982. Dr. Robert C. Seamans, Jr., Henry R. Luce, Professor of Environment and Public Policy at MIT, and Dr. Lawrence J. Korb, Assistant Secretary of Defense for Manpower, Reserve Affairs and Logistics, were asked to co-chair the Group. Membership was drawn equally from the university community and from DOD.

The Forum asked the Working Group to:

- review DOD needs for scientific and technical manpower, assess present DOD initiatives to strengthen the Department's engineering and science education activities, note potential deficiencies, and provide consultation and advice as appropriate.

- examine the present "deteriorated" environment in university engineering and science departments, assess the effectiveness of present DOD efforts to resolve these issues, and identify key leverage points in universities and in DOD where action could be applied.

- assess whether a support mechanism, modeled after the prepaid G.I. bill used to attract medical doctors, 1/ could be developed appropriately to fill the Department's needs for Ph.D. engineers and scientists; and examine the Department's continuing education programs in the Services to assess whether DOD should increase opportunities for military and civilian personnel to pursue full-time advanced study in universities.

Summary of Findings

A. DOD needs for scientific and technical manpower.

DOD has an important stake in the quality and supply of the national pool of engineers and scientists. Since DOD exerts a substantial influence over the

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1/ The program referred to is the Armed Forces Health Professions Scholarship Program.

entire system, it has a leadership responsibility to address the current crisis in engineering and science education.

- Of the 2.9 million scientists and engineers in the national workforce, 105,000 or 3.6% are employed by the Department of Defense in a civilian or military capacity. Of these 78,000 are civilians (72% of whom are engineers), and 27,000 are military officers.

- DOD also employs almost 740,000 technicians, 22,000 of whom are civilians. About 715,000 technically qualified individuals are in the military enlisted force and account for 40% of all enlisted personnel. Currently the Services are attracting sufficient numbers of qualified personnel for these positions, but the ability to recruit must be carefully monitored as military manpower requirements increase, the economy improves, and the enrollment of high school students drops.

- Beyond the 105,000 civilian and military engineers and scientists employed by the Department, another 13% of the nation's total S&E workforce is directly linked to Defense programs, budgets and policies.

- Forecasts undertaken by the National Science Foundation project potential shortages (5% to 10%) of electrical and electronic engineers employed by DOD contractors in 1987. Shortages greater than 10% in 1987 are predicted for aeronautical engineers, computer systems analysts and computer programmers.

- The shortages of both civilian and military S&E personnel within the Defense Department are reasonably well documented, but the quality aspects of the problem are not as well defined or understood.

- Experienced, journeyman level (GS-12/13) civilian S&E personnel, who make up the bulk of civilian S&E's in DOD laboratories, are being lost in large numbers. These losses include a small but significant number of exceptionally well qualified personnel. The military has been experiencing a comparable loss with a drop in the number of mid-career S&E officers (O-3, O-4, and O-5) in the last 10 years.

- DOD has not taken full advantage of continuing education opportunities which legislative authorities have provided to send current, full-time civilian and military personnel to graduate programs.

- Although the occupation of computer professional is a readily recognized shortage area, government occupational classifications do not properly identify these skills. As a result, it is not possible to identify requirements, match the supply, or to allow rational hiring, assignment or career planning in these fields.

B. Assessment of DOD initiatives to meet internal S&E personnel needs.

The Department has undertaken a variety of initiatives to develop the technical personnel it will need in the future. These efforts, however, could be strengthened [illegible] [illegible] [illegible].

- The Air Force bonus program for officers with critical S&E skills having between 4 and 12 years of service appears to be achieving desired retention results.

- ROTC scholarship programs are providing an increasing number of high-caliber new S&E officers having four-year service commitments.

- Civilian hires of new baccalaureate S&E personnel at GS-5/7 levels are currently in sufficient quantity. However, their quality does not appear to come up to the quality level of ROTC graduates.

- Cooperative education and work-related training programs for undergraduates (such as summer internships) have proven to be a most effective means to enhance recruitment and improve retention. Those involved in such programs have a high rate of conversion to full-time career employment in DOD, and they have been shown to have a good retention rate as well.

- The Defense Authorization Act of 1982 provided DOD laboratories with authority to contract with educational and non-profit institutions for the research services of students. This new authority, coupled with existing co-op education and other work experience programs, could become a highly effective recruitment tool for DOD R&D facilities.

C. Assessment of present "deteriorated" environment in university engineering and science departments and the related precollege foundation.

Research is fundamental to graduate education in engineering and science. Technological knowledge is not a static quantity but is rapidly advancing on many fronts. Engaging in research is an important educational experience. The products of research expand our knowledge and force changes in the engineering and science curricula.

The decline during the 1970's in government support for research at the nation's universities has resulted in a number of problems hampering both research and teaching.

- Deficiencies in research facilities and equipment are acute in most universities. Research instrumentation has grown more sophisticated and research costs have risen sharply while there has been a severe and prolonged erosion in the condition of many university laboratories. As a result, quality research efforts have shifted to a limited number of superior laboratories which have sources of funding enabling them to keep up.

- During the 70's the salaries of Ph.D.'s on university faculties did not keep up with salaries offered to S&E bachelors by private industry. Consequently, the supply of new Ph.D.'s in engineering has dropped considerably in recent years.

- Another consequence of this pay differential has been a luring away of high-caliber graduate students and young faculty out of the universities into challenging, well-paid positions with industry. This has generated a shortage of quality engineering faculty in many universities together

with unusually heavy teaching loads. This situation, in turn, has further lessened the attractiveness of a university teaching career for Ph.D.'s interested in research.

- The precollege foundation which supports S&E education in the universities has eroded as the number of high school students enrolling in math and science courses has dropped and the quality of education they have been receiving at this level has declined.

- Serious shortages now exist in the number of qualified math and science teachers at the high school level, and there has been a general decline in the quality of those who are teaching at this level.

- The deterioration of university research and education has been addressed by both the Senate and House Armed Services Committees, whose members have supported recent DOD initiatives in these areas. (See Appendix D).

D. Assessment of DOD remedial actions currently underway to strengthen engineering and science education.

DOD funding for basic research has been increased in recent years. The present policy of providing 7% real growth will have to be sustained for at least 5 years if university research capabilities are to be fully restored to the level they were in 1965.

- Current budget proposals have been made to allow increases for Defense research (if Congress cuts requests for these funds, as it has done in 16 of the last 20 years, there will be a continuing decline in real DOD investment in university research).

- The Army, Navy and Air Force have begun <u>graduate fellowship</u> and <u>specialized assistantship</u> programs in support of Defense related disciplines.

- In FY 83 DOD initiated a <u>University Research Instrumentation Program</u>. Jointly managed by the Services' research offices, the program is planned for five years at $30 million per year. To establish the program DOD requested an increase in FY 83 Congressional appropriations for the 6.1 research budget of $132 million (or 14% in real growth) over FY 82 funding. Of this amount, $30 million was set aside for the instrumentation program. Final Congressional appropriations, however, reduced the real growth increase in the 6.1 research budget from the requested 14% to 6.7%, of which 4.3% remained earmarked for the instrumentation program. With 4.3%, or almost two-thirds of the increase, earmarked for the instrumentation program, the net real growth in the FY 83 research budget was only 2.4% over FY 82.

- DOD has initiated a new <u>Independent Research and Development</u> (IR&D) policy supported through allowed overhead on DOD and NASA contracts, and designed to enable industrial contractors to support university research.

- There is a limited <u>Summer Faculty Program</u> in operation at DOD laboratories which provides summer research opportunities to university faculty members.

Summary of Recommendations

Based on the foregoing findings the Working Group on Engineering and Science Education makes the following recommendations to the DOD-University Forum:

1. Policies of support for university research should be continued. Any new initiatives should be funded with new appropriations so as not to threaten real growth in the research budget. (See page 41).

2. A study should be made of current qualitative aspects in the DOD S&E workforce. The dimensions of the qualitative problem are relatively unknown and need to be defined and assessed. (See page 41).

3. A focal point for S&E education should be established in OSD. An office should be charged with primary responsibility for developing and coordinating education and training policy Department-wide in all S&E-related areas. (See page 42).

4. Military undergraduate and graduate level S&E education and bonus programs should be continued and strengthened, including ROTC and graduate officer programs at the Air Force Institute of Technology, the Naval Post Graduate School, and civilian colleges and universities. Army and Navy should examine Air Force experience with bonus programs with a view toward considering implementing appropriate initiatives in their own Services. (See page 43).

5. Civilian precollege, undergraduate and graduate level assistance programs should be continued and strengthened. (See page 43). DOD should:

a. Utilize more fully precollege and undergraduate work-experience programs to provide a series of work and learning experiences for young people in DOD research facilities.

b. Increase utilization of financial support authorities now possible with the cooperative education program in order to meet the perceived need for educational assistance for undergraduate S&E students.

c. Establish a new graduate education program for civilians, not limited to current employees, to provide scholarships for experienced S&E personnel to obtain advanced S&E degrees in order to replace those experienced employees at mid-grade that are now being lost to industry and academia. A commensurate service commitment should be required.

d. Request Office of Personnel Management to identify a separate occupational skill code for civilians qualified and working as computer engineers; request higher pay scales for computer scientists similar to those for engineers to enable government to compete with the private sector for these scarce skills.

6. Opportunities for continuing education for civilian S&E's now employed by DOD should be increased. Administrative and legal limitations must be addressed in order to enhance utilization of currently available continuing education opportunities. (See page 45).

7. Interchanges between senior government S&E personnel and their colleagues in industry and academia should be increased. (See Page 47).

8. DOD graduate fellowship programs should be strengthened. Present programs emphasize quality but are very small. Programs should be increased without altering the emphasis on quality. (See page 47).

9. A comprehensive Faculty Development Program should be established. It is recommended that DOD formulate policies and programs to foster faculty development and to stimulate interest among younger faculty in research careers in areas important to the Department. (See page 48).

10. Development of university programs in Defense related technologies should be encouraged. A standing committee of DOD and university representatives should be established to encourage the development of university programs in response to specific Defense needs. (See page 49).

11. The DOD-University Research Instrumentation Program should be strengthened. It is recommended that this program be expanded with new appropriations to a level of $100 million per year and that it be sustained at that level for at least another 5 years. (See page 50).

12. A University Research Facilities Rehabilitation Program should be established. DOD should undertake a research laboratory rehabilitation program targeted on fields of interest to Defense, and encourage other agencies to begin similar programs each in furtherance of their particular interests and missions. (See page 50).

I. INTRODUCTION

Background

The Association of American Universities, the American Council on Education, the National Association of State Universities and Land-Grant Colleges, and the Department of Defense established the DOD-University Forum in February 1982. (See Appendix A for membership of the Forum). The impetus for establishing the Forum was a recommendation in two recent reports, one by the Association of American Universities[1] and the other by the Defense Science Board.[2] Dr. Richard DeLauer, Under Secretary of Defense for Research and Engineering, accepted the offer of the three associations to co-sponsor the Forum, and also agreed to be co-chairman with Dr. Donald Kennedy, President of Stanford University.

The Working Group

The capability of universities to educate engineers and scientists of the quality and in the quantity needed to secure our national economy and security is declining. The House and Senate Committees on Armed Services are fully cognizant of the erosion of our university base. For example, the April 13, 1982 Report of the Senate Committee states, "Manifestations of such erosion may be found in the fact that many laboratories and much research equipment are seriously outdated. Moreover, insufficient numbers of talented students and researchers are being attracted to careers in fields of science and engineering essential to the Nation's future security." The report goes on to support the proposed expansion of the DOD's university program, and admonishes the Department to strengthen the program as part of the fiscal year 1984 authorization request. In recognition of this disturbing trend, at its

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1/Report of the AAU Task Force on Defense Requirements and University Preparedness, A Report to the Committee on Science and Research of the Association of American Universities, October 1981.

2/Report of the Defense Science Board Task Force on University Responsiveness to National Security Requirements, January 1982.

first meeting on February 24, 1982, the Forum established a Joint Working Group on Engineering and Science Education. Dr. Lawrence J. Korb, Assistant Secretary of Defense for Manpower, Reserve Affairs and Logistics, and Dr. Robert C. Seamans, Jr., Henry R. Luce Professor of Environment and Public Policy, MIT, were appointed co-chairmen of the Group. The Working Group was asked to review DOD needs for scientific and technical manpower, to assess present DOD initiatives to strengthen the Department's engineering and science education activities, to note potential deficiencies, and to provide consultation and advice as appropriate.

The Working Group met for the first time on October 6, 1982, to initiate its work and to receive briefings from selected DOD staff. (See Appendix B for the membership of the Working Group).

On October 26, following a preliminary report by Dr. Seamans, the Forum asked the Group to weigh the relative merits of the various mechanisms used by the DOD to support engineering and science education, e.g., graduate fellowships, research assistantships on research projects, and equipment grants. The Working Group was asked to (1) examine the present "deteriorated" environment in university engineering and science departments, (2) assess for the Forum the effectiveness of the present DOD efforts to resolve these issues, the (3) identify key leverage points in universities and in DOD where action could be applied.

Dr. DeLauer also asked the Working Group to undertake two additional tasks:

a. Assess whether a support mechanism, modeled after the prepaid G.I. bill used to attract medical doctors, could be developed appropriately to fill the Department's needs for Ph.D. engineers and scientists.[1/] Such a program, carefully structured to avoid damaging ROTC programs, also would provide greater numbers of faculty and a national reservoir of talent.

1/The program referred to is the Armed Forces Health Professions Scholarship Program.

b. Examine the Department's continuing education programs in the military services and assess whether DOD should increase opportunities for its military and civilian personnel to pursue full-time advanced study in universities. Could a return to this policy provide stronger educational experiences for DOD personnel while improving the research and education base of universities?

The Working Group held a second meeting on February 25, 1983, to review an initial draft report and to receive additional briefings. The draft report was subsequently modified by the staff to accommodate the views of the Working Group as expressed at the February 25 meeting. On April 19, Dr. Korb and Dr. Seamans met with the Forum and, as requested, summarized the Working Group's progress and draft recommendations. The Forum encouraged the Working Group to complete its study in order to submit a final report to the Forum by the fall of 1983.

A third and final meeting of the Working Group was held on May 12, 1983, for the purpose of reviewing the report and incorporating final changes.

The final report is organized as follows:

- Section I: introduction with background and project tasking.
- Section II: a summary of DOD engineering and science manpower needs and programs.
- Section III: a discussion of the central issue; i.e., the requirement to provide for quality engineering education, especially at the graduate level.
- Section IV: findings and recommendations.

The recommendations are intended to increase the supply and to improve the quality of military and civilian engineers trained at the bachelor and doctoral levels, at job entry and advanced levels. It is hoped these recommendations will strengthen our university research and education capabilities in engineering and in related scientific fields of significance to the long-term DOD mission.

II. DOD NEEDS FOR ENGINEERS, SCIENTISTS AND TECHNICIANS

There are approximately 2.9 million scientists and engineers (S&E's) at work in the nation. The Department of Defense employs 105,000 (just 3.6%) of them in its civilian and military workforce of 3.1 million people. Of these approximately 78,000 are civilians -- 72% of whom are engineers -- and 27,000 are military officers. 1/

A rough distribution of the civilian engineers by major engineering field is:

- electronic and electrical engineering -- 17,000
- general engineering -- 9,700 (includes managers of engineering organizations)
- civil engineering -- 9,200
- mechanical engineering -- 8,400
- others (industrial, ceramic, nuclear, etc.) -- 11,900

DOD also employs almost 740,000 technicians, 22,000 of whom are civilians. About 715,000 technically qualified individuals are in the military enlisted force; they account for 40% of total enlisted personnel. Success in recruiting enlisted personnel with the capacity for technical training requires quality science and mathematics instruction at the high school level.

Beyond the 105,000 civilian and military S&E personnel directly employed by the Department, another 13% of the nation's total S&E workforce is directly linked to Defense budgets and programs. The DOD, therefore, has an important, although by no means dominant, stake in the quality and supply of the national pool of scientists and engineers. Other institutions and sectors of our economy cumulatively have an equal, if not greater, impact and leverage in working these problems. Nevertheless, the Department as a single entity exerts a substantial influence over the entire system and thus has a responsibility for assuming a leadership role in addressing the current crisis in science and engineering education.

1/DOD Active Full Time Civilian Employee Grade and Occupational Distribution, (DMDC-0718 Report), December 1981

DOD Requirements for Civilian Engineering and Scientific Personnel

A comprehensive Department-wide analysis of the 105,000 engineers and scientists employed by the Department has not been done. However, a DOD Task Force recently conducted an extensive study of those who are employed by the 71 DOD laboratories.[1/]

The 71 laboratories studied by this DOD Task Force employ 30,000 technical people, including 24,000 engineers and scientists. Since the laboratories employ almost a quarter of all civilian DOD engineers and scientists, they can be considered representative of DOD's total technical population for analytical purposes. Fig. 1 shows the distribution of laboratories among the 3 Military Services, the population of their technical personnel as compared to the total laboratory workforce, and the laboratory budgets, their geographical locations and sizes.

A comparison of DOD laboratory S&E's with national patterns reveals significant differences (see Fig. 2). DOD employs more engineers (62%) than scientists, a reversal of the national distribution. Within the DOD laboratories, a significantly smaller percentage of S&E's are women, while a somewhat higher percentage are minorities. A greater proportion of personnel in DOD's laboratories hold the Ph.D. The average age of S&E's in DOD laboratories is almost 5 years greater than the national average, a factor posing a potentially serious problem.

Considerable differences from the national picture are also seen in a distribution by academic disciplines (see Fig. 3). Forty-four percent of DOD laboratory engineers -- more than twice the national distribution -- are electrical or electronic engineers, and 57 percent of the scientists are in the physical sciences as compared to 15 percent of the nation's total pool

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1/DOD Laboratory Management Task Force, Study of Scientists and Engineers in DOD Laboratories, April 1982.

Fig. 1 - Location and Characteristics of DOD Laboratories

(End FY 81)

	Army	Navy	Air Force	Total
Number of Laboratories	39	21	11	71
Total Work Force	24,882	25,583	7,825	58,290
Total Technical Work Forc	10,735	13,871	5,576	30,182
Total Budget ($B)	2.4	2.2	1.2	5.8
Location:				
Northeast (MA, NH, RI, NY)	5	3	2	10
DC Metropolitan Area	8	4	0	12
Midatlantic (NJ, PA, MD, VA)	16	2	0	18
South (FL, AL, MS, LA)	4	4	2	10
Midwest (OH, IL, MI, CO)	3	1	3	7
West (TX, NM, CA)	4	7	4	14
Laboratory Size				
100 or Fewer Civilian S&E	15	9	3	27
101 - 499 Civilian S&E	21	5	6	32
500 - 999 Civilian S&E	2	0	1	3
1,000 or More Civilian S&E	1	7	1	9
Total	39	21	11	71

Source: Study of S&E's in DOD Labs, April 1982.

Fig. 2 - A Comparison of Scientists and Engineers in DOD Laboratories with National Averages

(1980 data in percent)

	DOD Labs	National
Percent Engineers	62	48
Percent Scientists	38	52
Percent Women	5.2	12.7
Percent Minority	6.9	4.9
Highest Degree		
Doctor	14	11
Master	26	24
Bachelor	57	63
Less than Bachelor	3	2
Average Age	42.2 Yrs.	37.6 Yrs.

Source: Study of S&E's in DOD Labs, April 1982.

of physical scientists. The opposite is true in the social and life sciences, with far fewer in these fields needed by DOD.

Fig. 3 - Comparison of Scientists and Engineers in DOD Laboratories with National Inventory, by Academic Disciplines
(1980 Data in Percent)

	DOD Laboratories	National
Engineers		
Electrical/Electronic	44	18
Mechanical	20	17
Aeronautical	10	3
Civil	4	14
Chemical	3	5
All Other	19	43
	100	100
Scientists		
Physical	57	15
Mathematical	23	8
Social	7	22
Life	6	25
Computer	3	23
Environmental	3	6
	100	100

Source: Study of S&E in DOD Labs, April 1982.

There is a problem in these data with the category "computer scientists". DOD in fact employs computer scientists in a proportion closer to the national level. However, ambiguities in the reporting categories have undoubtedly caused some of these specialists to be recorded as mathematicians and electrical engineers. The misclassification of computer scientists is seriously hindering an understanding of S&E supply and demand. Recommendation IV, c, in Section IV addresses this issue.

A preliminary examination of recruiting and retention rates in the DOD laboratories shows that on average the vacancy rate across all laboratories at the end of fiscal year 1981 was about 5 percent. During that year DOD was able to fill all entry-level (GS 5-7) positions despite adverse salary differentials between the public and private sectors. Nevertheless, over the same time frame,

19 laboratories (with almost 11 percent of DOD's total laboratory scientific and engineering population) reported a vacancy rate of over 10 percent for scientists and engineers; 5 laboratories had vacancy rates of between 20 and 23 percent. In addition, large losses (58 percent of all departures) were found at the GS-12 and 13 -- generally mid-career -- levels. These S&E's make up 63% of all S&E's in the DOD laboratories. Losses in these grades for FY 81 were 6.4%. The perceived problem as reported by laboratory directors is the drain of their most capable people.

Efforts to enhance recruitment and retention of scientists and engineers show cooperative education and work-related training programs for undergraduates to be most effective. Thirty-six laboratories have active programs. Approximately 33% of all participants in these programs are recruited into the DOD workforce, and 66% of these stay beyond 3 years. In September 1981, 829 students were participating in the DOD laboratory cooperative programs.

Continuing education programs are authorized in civil service legislation and regulations; wide flexibility in its use is allowed. Long-term training (in excess of 120 days) is a proven and reliable method for developing skills, as well as for attracting and retaining well qualified S&E's. However, there is great variation in the care with which individual laboratories forecast their needs and plan their training programs. Only 22 of the 71 laboratories surveyed reported using long-term training to upgrade their staffs during the past five years. In the laboratories which did report use of long-term training, only 1%-3% of the S&E workforce participated. The Task Force supported a strengthening of both long-term training and cooperative education programs.

DOD Requirements for Military Engineering and Scientific Personnel

The Task Force examined military S&E vacancy rates in the laboratories and found an average vacancy rate of 17 percent. The Air Force reports the lowest

rate (13 percent); but, because there is a substantial military S&E population in Air Force laboratories, this represents a sizeable shortage.

In fiscal year 1979 the Air Force recognized a severe engineer shortage; since then, it has made substantial progress in alleviating it.

Fig. 4 - Air Force Officer Engineer Manning (End FY 82)

	Auth	Asgn	Short	% Staffing
Metallurgist/Nuclear	97	91	6	94
Acquisition Program	978	697	281	71
Development (electronic, mech, astro, aero)	4507	4114	393	91
Program Mgmt	35	50	+15	143
Comm-Electonics	560	471	89	84
Civil (arch, civil, indus, electrical)	1915	1827	88	95
	8092	7250	842	90

Source: USAF - MPCROS-5.

At the end of FY 82 the Air Force was short 842 engineers, as shown in Fig. 4. However, by the end of FY 83 the shortage is expected to be only 350. By the end of FY 84 aggregate engineer manning is expected to meet the full requirement, although there will continue to be a shortage in electrical/electronic engineers. The Air Force attributes this encouraging recovery to the engineer continuation bonus, as well as to the general improvement in military compensation.

It should be noted that similar shortfalls exist in the other Services; the Air Force figures are cited only as an example of one Service and are not intended to convey the full range of the problem across the Military Departments. As a matter of fact, the Services project that they will have an aggregate shortage in 1987 of about 6,000 military officers with graduate degrees in science and engineering. These officers are needed to fill selected "validated billets" which have been designated as requiring technical expertise equivalent to that acquired through graduate degree programs in specific disciplines. Additional

qualified officers are required to fill out the inventory to allow degree-holding officers to meet other military job requirements and career-development objectives. The shortage of qualified degree-holders is largely due to reductions in funds available for fully funded graduate education in the 1970's. This resulted in a depleted inventory that can be refilled only over an extended time.

As pointed out earlier, the major numerical requirement for people with technical backgrounds is in the enlisted force. The Services use the results of the Armed Services Vocational Aptitude Battery (ASVAB), a test given to each applicant for military service, to determine whether a person has the requisite ability to succeed in technical training. There are presently 715,000 positions in the enlisted ranks which require a specific technical aptitude. Based mainly on anticipated growth in the enlisted force required to man a larger and more highly technical military force, the Services forecast a continuing increase in requirements for technically qualified people throughout the next two decades. At the moment, the Services are attracting sufficient numbers of qualified personnel to meet their needs in the enlisted ranks; but, as requirements increase, the economy continues to improve, and high school enrollments decrease, problems seem likely to develop.

The National Pool of Engineers, Scientists and Technical Personnel

The Department of Defense's FY 1983 Annual Report to the Congress proposed increases in real defense expenditures of 48 percent between 1982 and 1987. The FY 84 report reflects a continuation of these trends. To identify potential labor market imbalances over this period, the Division of Science Resources Studies of the National Science Foundation undertook a study to project future engineering, scientific and technical employment demands using two simulation models. Employment requirements for this study were projected using NSF-generated data in conjunction

with the Defense Interindustry Forecast System developed by Data Resources, Incorporated. Four sets of employment projections were generated based on varying assumptions of macroeconomic activity and Defense-expenditure levels. These conditions were selected to provide lower and upper bounds for future demands in various critical categories. The supply projections of scientists and engineers were generated using a stock-flow model, developed under contract to NSF, which incorporates supply response to fluctuations in employment demand. Since the study was completed, however, many economists have begun to make projections of GNP growth which exceed the upper bounds that were used. Thus the shortage projections which were published may be very conservative.

The ranges of total national employment and growth in scientific, engineering, and technical occupations between 1982 and 1987 which were projected by the NSF study are summarized in Fig. 5. These projections are based on an Occupational Employment Statistics survey provided by the Bureau of Labor Statistics. Employment estimates for 1982 are based on actual economic performance in the first half of the year.

Fig. 5 - Projected Range of Employment Growth from 1982 to 1987

Occupation	Actual employment 1982 (Thousands)	Projected low economic growth/ low defense scenarios		Projected high economic growth/ high defense scenarios	
		Employment 1987 (Thousands)	Annual growth rate 1982-87 (Percent)	Employment 1987 (Thousands)	Annual growth rate 1982-87 (Percent)
Scientists....	730	850	3.0	900	4.3
Engineers.....	1,140	1,300	2.7	1,400	4.2
Technicians...	1,470	1,650	2.3	1,750	3.5

Source: NSF 83-307, Science Resources Studies Highlights.

The NSF study evaluated four scenarios for the 1982-87 period representing combinations of low and high macroeconomic activity (1.6% and 4.3% growth per

year respectively) and low and high growth rates in real Defense expenditures (3.1% and 8.1% per year respectively). Based on these scenarios, growth in employment for each of the major occupational categories -- engineers, scientists and technicians -- is projected to range from 2.5% to 4.0% per year.

Shortages (representing at least a 10% shortfall in supply) are projected for aeronautical/astronautical engineers and computer specialists. By 1987, the shortfall for the former will vary from 15% to 45%, representing approximately 10,000 to 35,000 personnel; for the latter, the comparable range will be 15% to 30%, or about 115,000 to 140,000 personnel. At high projected levels of Defense spending, the shortfall of electrical/electronic engineers is estimated to be almost 10% of supply, or roughly 30,000 personnel. It is also possible that the projected rates of growth for industrial engineers could be understated and that this may result in potential shortages by 1987.

Job opportunities can be expected to draw engineers into fields where shortages are projected. However, this shift assumes (perhaps erroneously) that engineering schools can further expand their enrollments. In matter of fact, engineering schools are already at saturation in these fields, and many are now limiting their enrollments. Since 1973 enrollments have increased 108% while faculties have only increased 14.5% (see Fig. 6). The result has been an increase of 81% in the ratio of students to teachers -- from 14 to 20. Compounding this saturation problem is the current faculty shortage represented by about 1700 unfilled tenure track positions. The overcrowded condition of engineering classes may be stated yet another way: about 5000 additional new faculty would be required in order to return to the student-to-teacher ratios which existed in the mid-1960's.

Figure 6. Growth of Engineering Undergraduate Enrollment and Faculty Size

	Year (Full Term)			
	1968/9	1973/4	1981/2	% Change 1973/4-1981/2
Undergraduate Enrollment	239,242	186,705	387,577	107.6
Faculty Size	15,716	16,859	19,310	14.5
Student-to-Teacher Ratio	15.2	11.1	20.1	81.1

Source: American Society of Engineering Education (8/82).

The NSF study has several important limitations. First, it focuses on overall demand/supply projections in S&E occupations, but makes these projections on an aggregate basis. High demand sub-specialties cannot be assessed and, in fact, may not follow the aggregate indications obtained. Second, the qualitative dimension of graduate students and degrees awarded are not evaluated. Third, foreign graduate students and their impact on academia and on national demand/supply are excluded. Fourth, the projections are based on conservative national growth estimates that now appear to understate probable economic conditions. The NSF study model does not allow examination of these specific questions below the aggregate level presented. These sub-specialty areas are, however, precisely what pose the most difficult problems and policy questions for DOD.

Reporting and categorization limitations in the NSF model probably understate the supply projection for electrical/electronics engineers, while overstating it for computer scientists. It is not known how serious this categorization problem is. If sufficient EE's and other engineers were recategorized as computer scientists, it would not significantly change the shortage situation for computer scientists, but it could better define the supply of electrical/electronics engineers as a clear shortage situation.

The NSF study indicates that projections of S&E employment are more sensitive to variations in Defense spending than to variations in macroeconomic activity

due to the fact that Defense spending impacts so heavily on the high-technology manufacturing industries. Among S&E occupations, Defense expenditures have their strongest impact on the engineering work force.

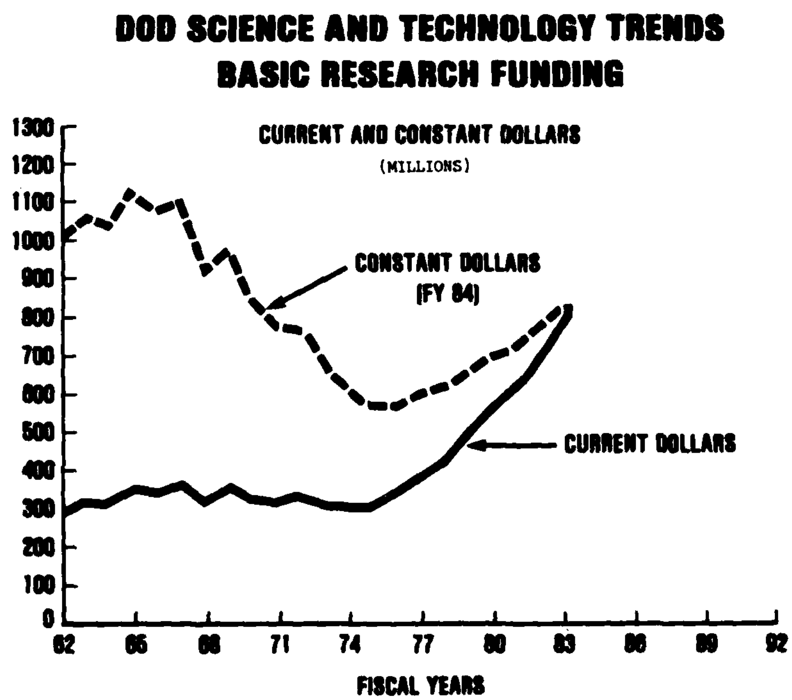
Finally, shortages can have a serious effect on those sectors, such as academia, which cannot effectively compete for scientists and engineers with the higher salaries and state-of-the-art equipment available in industry. Defense industries probably will succeed in obtaining the personnel they need to execute the Defense plan, but the cost to our universities and government laboratories of that success may be substantial.

Although the data on the supply and demand for scientific and technical manpower required for national defense are incomplete, it appears that civilian vacancies between 5% and 20% currently exist in DOD laboratories, and there are unfilled laboratory positions for military officers ranging from 13% for the Air Force to 17% for the Army and Navy. Defense expenditures appear to have the strongest impact on the engineering workforce, but enrollment in all the scientific and technical areas must be encouraged and monitored continuously since national security depends on both the quantity and quality of civilian and military S&E personnel.

III. OUR TROUBLED EDUCATIONAL SYSTEM AND THE PRESENT DOD RESPONSE

The Problem is Quality

The essential problem for our universities is a qualitative one resulting in large part from the decline in national commitment to and investment in research and related graduate education in engineering and the sciences from the mid-1960's until the mid-1970's. During that period DOD research support in real terms dropped from approximately $1150 million to $600 million -- a drop of almost 50% (see Fig. 7). The Department's investment in engineering and science research and education fell far below levels necessary to maintain a productive relationship between DOD and the universities.



Source: Office of the Secretary of Defense (OUSDRE), (6/83)

Figure 7.

During the same period, many corporate organizations also reduced their basic research efforts. In effect, they relied upon the universities and government laboratories to provide them with the basic research results; the nation failed, however, to recognize that its investment in basic research, particularly in our universities, was falling to inadequate levels. The situation in many other major countries was quite different. As U.S. investment in civilian (non-military) research and development declined in real terms, France, West Germany, Japan and the United Kingdom increased their R&D expenditures substantially. (See Figs. 8 and 9 below).

Fig. 8 - National Civilian Research and Development Expenditures
(Percentage of U.S. Expenditures)

	1964	1969	1975	1978	1979
France	11.7	12.8	19.3	18.7	19.7
West Germany	12.1	14.6	34.3	37.9	41.7
Japan	10.9	17.1	39.0	53.5	50.5
United Kingdom	12.8	11.5	13.5	13.9	N/A
Totals	47.5	56.0	106.2	124.0	N/A

Source: Congressional Research Service, Library of Congress. "U.S. and Other National Civilian R&D Trends," June, 1983.

Fig. 9 - National Civilian Research and Development Expenditures
(Expenditures as Percentage of GNP)

	1964	1969	1975	1978	1979
U.S.	1.73	1.83	1.65	1.65	1.71
France	1.39	1.63	1.45	1.40	1.42
West Germany	1.26	1.64	2.08	2.10	2.26
Japan	1.51	1.71	2.00	1.98	2.09
		1969			1978
United Kingdom	1.51	1.76	1.47	1.57	N/A

Source: Congressional Research Service, Library of Congress. "U.S. and Other National Civilian R&D Trends," June, 1983.

Research equipment and facility needs are a particular problem. As research instrumentation steadily grew more sophisticated, the cost of doing research went up sharply. As a result of the deterioration of research funding, high-quality research efforts tended to shift to a limited number of superior laboratories in industry, government and universities. Very strong research groups in those laboratories now dominate the research scene in selected fields. In the past, it was possible for researchers to offset some equipment disadvantages through more ingenious experimental design, but the nature of modern measurement, and the sophistication of the analysis required to use information from such measurements, are such that a very great advantage accrues now to the well-equipped national laboratories or a few university laboratories. In effect, the traditional strength of faculty ingenuity is being overwhelmed by the sheer analytical power available only in certain laboratories. In addition, research laboratories, including many in which DOD programs are carried out, now are outdated and need to be replaced or modernized. The consequences of this situation are diminished research productivity and competitiveness and compromised quality of graduate education programs in equipment-dependent fields. For a fuller discussion of equipment and facilities problems see the reports of the Defense Science Board and the AAU referenced on page 1.

The present supply of Ph.D. students also is influenced by previous experience. During the 60's there was a substantial federal investment in support for graduate students; but the numbers of federally funded fellowships declined precipitously from 51,000 in 1968 to fewer than 10,000 in 1983,[1/] and there are only about 1,600 of them in engineering and science.

In the early 70's, university expansion slowed and there was alarm that too many Ph.D.'s were being produced. The corporate commitment to research waned,

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1/The Federal Role in Graduate Education: A Position Paper. Association of American Universities, January 25, 1983.

and many companies expressed concern about the oversupply of Ph.D. engineers. It was suggested that the numbers of graduate engineers needed for the nation could be met by a small number of universities with outstanding research facilities. Support for graduate research was curtailed in some of the mission-oriented federal agencies, mainly NASA and DOD, and research budgets in others did not keep pace with inflation.

Demand for engineers began to drop steeply in some sectors in reaction to the cutback in some of the major space programs in the late 60's and the phase-down of the military effort in Southeast Asia. With this temporary dislocation of the demand, enrollments in engineering dropped. A few years later the demand began to rise dramatically, and salaries and intense recruiting efforts decimated the pool of first-year graduate students. Many students did not opt for graduate school because they were diverted by the opportunity for immediate employment and a rapid return on their investment in education. At least for the last 8-9 years the demand for baccalaureate engineers has exceeded the supply, and salaries have been rising steadily. For a period in the early 70's the salaries of engineering bachelors escalated more rapidly than salaries of engineering Ph.D.'s, particularly those on university faculties. As a consequence the total number of Ph.D. graduates has dropped. Nearly half the Ph.D.'s awarded now go to foreign nationals and the numbers of advanced engineering degrees conferred to U.S. citizens at both the masters and doctoral levels declined significantly between 1971/2 and 1981/2 (see Fig. 10). Not much is known regarding the ultimate destination of foreign engineering Ph.D.'s. Some opt for academic careers in the U.S. Others may take federal jobs in government, or in industry, but about half return to their own or other foreign countries. It is clear, however, that foreign engineering Ph.D.'s cannot obtain U.S. security clearances and are not available for direct DOD employment.

Fig. 10 - Advanced Engineering Degrees Conferred in U.S.

	Degrees/Awarded			Degrees Awarded To Foreign Nationals			Percent of Degrees Awarded to Foreign Nationals		
	1968/9	1971/2	1981/2	1968/9	1971/2	1981/2	1968/9	1971/2	1981/2
MASTERS	14,980	17,356	18,289	1,784	2,939	5,216	12	17	29
DOCTORS	3,387	3,774	2,887	410	773	1,167	12	20	39

- Number of advanced degrees awarded to foreigners almost doubled between 1968/69 and 1971/2 and tripled by 1981/2.
- Number of master degrees awarded to U.S. citizens has remained nearly constant from 1968/9 to 1981/2.
- Number of doctoratal degrees awarded to U.S. citizens has dropped by 42% from 1968/9 to 1981/2.

Source: ASEE, April 1983.

During the same period, most of the major public universities and many private ones experienced severe financial pressures. The golden age of the late 50's and early 60's saw the development of new programs. The needs of public universities were given high priority by state legislatures. Now priorities have shifted, and many public universities are experiencing fiscal stringency. In the last decade severe inflation, restrictions on growth, and, in some cases, absolute reductions of resources, have depleted many engineering programs both in terms of human and fiscal resources. As appointments of new engineering faculty are limited, the average age of faculty is increasing. Faculty teaching loads have increased substantially because enrollment increases have far exceeded the capacity of faculty to absorb them. Many regard this increase as a threat to the quality of engineering education. The increased instructional load makes it difficult for faculty to engage in scholarly activities and remain on the frontier of technology. As students observe the faculty experiencing these pressures, undergraduates develop negative attitudes toward graduate study, and graduate students are more inclined toward a career in industry or government laboratories.

The Quality of Engineering and Scientific Personnel in Government and Industry

An attempt was made last year in the study of S&E personnel in DOD laboratories (previously cited) to assess the quality of the S&E employees (see Fig. 11). A large majority of the directors surveyed believed that the quality of their workforce was good to excellent. A lesser number, just over half, thought that their workforce was current in their field. Of responding laboratory directors, 37 percent believed their new hires were equal in quality to people hired five to ten years ago; 21 percent believed that quality is better now, but 27 percent thought that quality is not as high as it was.

Fig. 11 - Laboratory Directors' Opinion on Laboratory S&E Quality

- Quality of Workforce

  80% report good-to-excellent, very high
  20% report fair-to-good, adequate

- Currency of orkforce

  60% report good-to-excellent, very high
  40% report fair-to-good, adequate

- Quality of Entry & Journeyman Level Hires (Compared to 5-10 years ago)

  21% report higher
  37% report same
  27% report not as high
  15% made no response

Source: Study of S&E in DOD Labs, April 1982.

A less sanguine conclusion was reached by the 1982 Army Science Board Summer Study on Science and Engineering Personnel.[1/] On the basis of interviews with laboratory directors, middle managers and bench-level S&E's, the Board concluded that the quality problem was much more severe than the quantity problem. Although the data are far from conclusive, they do reflect a wide spread concern.

1/Army Science Board 1982 Summer Study, Panel on Science and Engineering Personnel, September 1982.

Specific indicators are not available to define or assess the future quality of American scientists and engineers; however, we do know a great deal about past U.S. scientific accomplishments. In the 35 years since the end of World War II, this country has established and maintained preeminence in many fields of knowledge. Evidence of U.S. scientific and technological leadership is found, to cite a few examples, in the record of the manned space-flight program, dramatic advances in computer engineering, breakthroughs in our understanding of genetic processes, and new insights into the fundamental structure of matter. In recognition of pioneering work such as that cited above, American scientists and engineers have won 51 percent of the Nobel Prizes (excluding prizes for peace and economics) awarded in the post-World War II period. Publication activity and citation analyses provide further evidence for the high quality of work produced by U.S. scientists and engineers in the past.

On the negative side, several indicators now reveal a relative decline in the technological advantage of U.S. industry as compared with its foreign competitors. These indicators include relative changes in labor productivity and relative numbers of U.S. patents granted to U.S. and foreign applicants. No data has been collected to prove the exact relationship between the quality of the science and engineering labor force and overall industrial productivity, though it is known that there are at least correlations between productivity and the rate of investment put into research and development. It is at least plausible that the level of technical competence of all workers in an industry, including scientists and engineers, bears directly on the problem of improving industrial productivity. If so, then the qualifications of students who intend to enter science and engineering occupations are germane to the broad question of the adequacy of science and engineering education for long-term national needs. Although it is clear

that the current U.S. technical labor force contains a large share of the world's most productive scientists and engineers, some observers question whether the U.S. will be able to maintain this level of quality.

The percentage of the science and engineering labor force holding doctoral degrees is one indirect measure of the ability of the U.S. to compete scientifically and technologically. A labor force better educated in science and engineering is better prepared to keep abreast of rapidly expanding scientific and technical knowledge and to explore new areas of investigation, such as recombinant DNA research. From 1973 to 1979 the overall number of active science and engineering Ph.D.'s in the U.S. grew from 223,000 to 317,000 -- an increase of 42 percent. This increase was generated in large part by a doubling of working Ph.D.'s in the natural sciences between 1960 and 1978; however, the overall figures mask the fact that during the same period, annual production of engineering doctorates decreased by 30%.

In the final analysis, the quality of science, mathematics and engineering education programs can be judged with certainty only by the productivity of the S&E's they produce. This takes a long time, too long a time to wait before taking necessary corrective actions. Many persuasive indicators are causing a growing concern throughout academia, industry and government over an erosion of quality. Some of these indicators are quantified and defendable, others are not. But together they indicate the presence of a broadly based, multi-faceted problem of concern to the Department.

The Weakened Precollege Foundation

> If an unfriendly foreign power had attempted to impose on America the mediocre education performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves. We have even squandered the gains in student achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems

> which helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral education disarmament.1/

It is well documented that high school graduates are receiving less mathematics and science in their curricula. Since 1972, the percentage of students enrolling in these classes (the major source of S&E students) has declined by four percent. Because the size of the high school graduate population has risen by almost three percent since 1972, the impact on the current pool of scientists, engineers, and military recruits with technical aptitude has been insignificant. In the 1980's, however, the annual number of new high school graduates is expected to drop significantly. This together with the smaller percentage of students studying mathematics and science is likely to have a dramatic effect on the numbers of young people capable of pursuing technical careers.2/

The quality of this pool is also causing concern. Science and engineering may not be able to attract as many high-caliber students as other professions in the future. The National Assessment of Educational Progress (NAEP), funded by the National Institute of Education, has completed assessments reflecting changes in mathematics achievement during the 1970's. These show significant declines in the ability to make mathematical applications involving the use of mathematical knowledge, skills and understanding in problem solving. At this time colleges and universities are skimming the top high school graduates into engineering programs, but future shrinkage in the pool of high school graduates may not allow this type of approach to continue.

These findings are particularly worrisome in light of what appears to be a more general qualitative deterioration as reflected in the performance of all precollege students on various achievement tests -- for example, the SAT used by many colleges in making admission decisions. Between 1970 and 1981, average

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1/"A Nation at Risk: The Imperative for Educational Reform; A Report to the Nation by the National Commission on Excellence in Education," April 1983.

2/The data on high school students are excerpted from NSF Report 82-318, "Science & Engineering Personnel; A National Overview."

verbal SAT scores declined by 36 points (460 to 424), while average mathematics scores declined by 22 points (488 to 466). Declining scores are believed to reflect a nationwide trend toward less stringent high school graduation requirements. Only one-third of the nation's 17,000 school districts now require more than one year of mathematics and science for graduation. Furthermore, colleges and universities have reduced the amount of mathematics and science required for admission.

The High School Teacher Shortage [1]

Recent studies confirm the fact that classroom teachers play a pivotal role in the education of students. While these teachers do not bear a total responsibility for the curriculum, they have a great deal of influence in deciding the content of their courses. Furthermore, it has been demonstrated that science and mathematics teachers have an important influence on the achievement levels of the students they teach as well as on their decisions about whether or not to take more advanced courses in science and mathematics. Given the central importance of these teachers, there are two reasons for concern.

First, there is presently a significant number of unfilled teacher positions in mathematics and physical science at the secondary school level. The number of people seeking entry to educational preparation programs at teachers colleges and universities has decreased markedly. A national survey found that at the end of the 1977-78 school year almost 10 percent of the mathematics and physical science teaching positions in the secondary schools of the United States were vacant. In addition, some observers believe that the quality of new mathematics and science teachers has declined. Unfilled teacher positions in mathematics and physical science evidently result both from a lessening in the attractiveness of science and mathematics teaching careers and from more desirable employment

1/Excerpts from "Science & Engineering Education for the 1980's and Beyond." NSF, October 1980.

opportunities outside of the teaching profession. When positions cannot be filled through new hiring of qualified instructors, they are often filled by teachers having lower subject-matter qualifications or by the transfer of tenured teachers from other subject areas. Thus, inevitably, many secondary school mathematics and physical science teachers have insufficient training to teach courses in these subjects. This assessment is reinforced by data from a nationwide survey which indicated that a sizeable number of secondary school science and mathematics teachers feel inadequately qualified to teach one or more of their courses.[1/]

The second reason for concern is the erosion of support systems for secondary school teachers. Supervision in the nation's high schools has been reduced as a result of financial retrenchment. There are relatively fewer people available outside the classroom to provide quality control or to assist teachers with pedagogical problems. The teachers, however, clearly need this help. A total of 67 percent of science, mathematics, and social studies teachers reported needing assistance in obtaining information about instructional materials, and over half of these teachers said they needed the help of laboratory assistants or para-professionals.[2/]

Laboratory experience is essential for adequate instruction in science. Over 25 percent of school teachers and administrators consider inadequate facilities to be a serious problem in their science programs. There is, however, evidence that teachers may not make frequent use of these facilities even when they are available. This may be due either to fill-in teachers who feel inadequate in the laboratory or to the lack of para-professionals and laboratory aides.

1/I. R. Weiss. Report of 1977 Survey of Science, Mathematics & Social Studies Education. Washington, DC: U.S. Government Printing Office, 1978, p. 60.

2/Ibid.

Another facet of the erosion of support systems for teachers is a decline of opportunities for faculty development. There has been a sizeable drop in federal support for summer and in-service teacher institutes since the peak funding years of the late 60's, and this support has not been replaced by local sources.[1/] One specialist who made an extensive evaluation of the summer institute program concluded that it is generally successful in making a significant, positive impact on secondary school science and mathematics education. In addition to providing continuing educational opportunities to science and mathematics teachers, summer and in-service institute programs provide an important incentive to secondary school teachers by allowing them to associate with their school, college and university peers and learn from the experience of others about improved teaching and curriculum approaches.

University Related Quality Problems

It is a well documented fact that the nation's research universities currently face significant problems that will take time, investment and national resolve to correct. Among the problems which these universities face are (1) increasingly obsolete research laboratories and equipment, (2) a serious shortage of faculty qualified to teach state-of-the-art technology, (3) smaller percentages of U.S. citizens in graduate programs (together with a correspondent increase in the percentage of foreign participation in S&E graduate education), (4) pay differentials that are enticing faculty and prospective graduate students out of our universities, (5) poorly prepared high school graduates, (6) an inescapable decline in the number of college age youth and (7) the cumulative effects of prolonged erosion in the general quality of education in science, engineering and mathematics now provided to precollege, undergraduate and graduate students.[2/]

1/The FY 84 NSF budget proposes to establish the institute program again.

2/Research laboratory equipment problems were well documented in "Report of the Defense Science Board Task Force on University Responsiveness to National Security Requirements" OUSDR&E, January 1982.

There are, today, severe shortages of qualified faculty members in most fields of engineering, as well as in the computer professions. Industries have expanded their research and development efforts and have increased the rate at which new, sophisticated products are introduced. To effect this, they are luring many high-quality graduate students and young faculty members away from the universities into challenging, well-paid positions. At the same time, they are making such attractive job offers to bachelor's degree recipients that many who would once have gone to graduate school now opt for positions in industry. The net effect has been a reduction in the ability of universities to provide education in engineering and the computer professions. This is inspite of the fact that undergraduate demand for these academic disciplines is more intense than ever. Unless the problem of faculty erosion is alleviated, it is possible that many engineering schools and departments that educate engineering and computer professionals may have to reduce their enrollments during this decade, and thus cause a reduction in the number of trained people that this nation's future requires in these fields.

The current shortage of graduate students and faculty members creates unusually heavy teaching loads which make academic jobs less attractive to those interested in research. The faculty erosion problem can be alleviated in part by improving both the research and teaching environment in engineering schools and computer departments.

Most authorities believe that the presence of a body of younger doctorates is essential to the continued vitality of research in the universities. Efforts to increase the number of recent doctorates in faculty positions, however, are likely to be influenced by the overall financial health of the universities,

which in turn are affected by trends in enrollment, and alternative employment opportunities.

Another important problem in engineering education is the severe lack of modern equipment required for instructional purposes at the undergraduate level. Recent studies have shown the need for $1 billion to $2 billion worth of equipment to replace obsolete equipment and to accommodate the doubling of engineering enrollments over the past decade. During the past decade, computer-aided design and computer-assisted manufacturing methods have provided important gains in productivity for some large companies in this country. The apparatus required to teach these methods to students, however, is generally unavailable in engineering schools. Consequently, a good deal of the instruction being offered may in fact be obsolete. While this problem may not be insurmountable for a large employer who can afford on-the-job training for new personnel, it can have deleterious effects on smaller companies and industries which have traditionally depended upon new graduates for information about the latest developments in engineering practice.

Increases in undergraduate engineering enrollment coupled with increasing faculty shortages have decreased the opportunity for interaction between students and teachers. A close and continuing relationship between students and teachers is essential for quality S&E education. It is believed by some that the reported shortage of faculty is actually understated because institutions do not realistically think they can fill even the stated vacancies. Adjusting the student-to-teacher ratio to the 1968 level would require 5,000 new faculty in addition to the currently identified shortage of 1800 instructors. The practical short-term remedy taken by more and more colleges and universities is to limit engineering undergraduate enrollments.

The Defense Department, by itself, cannot solve these problems. But certain steps have been taken to exert DOD's leadership in this area.

DOD Corrective Actions Currently Underway

Numerous programs have been initiated by DOD and the Military Departments to alleviate both current and projected shortfalls of scientific and engineering personnel, uniformed and civilian. In addition the Department has taken some steps to help ensure an adequate flow of scientifically literate students into undergraduate programs. Several new remedial and special-focus programs designed to strengthen scientific and technical education at elementary, secondary, undergraduate, and graduate schools have been developed by each of the Services. Complete information on all of these programs, however, is not now available because the activities generally are small, fragmented and not centrally managed or coordinated among the Services. While a decentralized approach encourages S&E establishments to develop programs suited to their own particular needs and capabilities, it also results in an obvious lack of coordination and central review of policy and program development. The table on pages 30 and 31 summarizes many of these programs and gives a picture of their breadth and diversity.

In addition to the many targeted initiatives across the educational system, the Department has taken several steps designed specifically to improve the nation's university research and advanced education capabilities.

Defense research declined by a factor of two in constant dollars, i.e., in purchasing power, from 1965 to 1975. This decline was reversed in 1976, and the present Administration has continued to request steady budget increases for Defense research. The Congressional appropriation for the DOD 6.1 research program for FY 83 is $779 million, with approximately 45 percent of this figure supporting university research. If Congress cuts the FY 84 request for 6.1

SUMMARY OF DEFENSE S&E EDUCATION INITIATIVES

SPONSOR	PROGRAM TITLE	FY 83 PARTICIPANTS	ESTIMATED COST (THOUSANDS)
Precollege			
Army	Junior Science & Humanities Symposia	7,300	$650
	Science & Engineering Fair Program	60,000	30
	Research & Engineering Apprenticeships	120	275
	Uninitiated Introduction to Engineering	140	100
	International Mathematical Olympiad	8	10
	Armed Forces Orientation in Engineering	30-40	UNKN
	Pre-Freshman & Cooperative Education Program (ERADCOM)	25-30	20
Air Force	Precollege Technical Orientation Program	UNKN	UNKN
	Research & Engineering Apprenticeships	10-20	UNKN
	Uninitiated Introduction to Engineering	16	80
Navy	Research & Engineering Apprenticeships	225	UNKN
	Pre Co-op Program	130	UNKN
DOD	Partnership for the Development of National Engineering Resources (Defense Communications Agency)	UNKN	UNKN
College			
Air Force	Airman Education & Commissioning Program	1,023	1,670
	ROTC - Science & Engineering Scholarship Emphasis (85% for S&E Studies)	7,500	39,900
	AF Institute of Technology Undergraduate Engineer Conversion Program	417	2,900
	College Senior Engineering Program (CSEP)	269	3,300

SPONSOR	PROGRAM TITLE	FY 83 PARTICIPANTS	ESTIMATED COST (THOUSANDS)
Navy	ROTC - Science and Engineering Program	5,000	14,000
	Co-op Education Program	2,200	UNKN
	Federal Junior Fellowship Program	111	UNKN
Graduate			
Navy	Office of Naval Research-Graduate Contract Research Programs	2,200	UNKN
	Co-op Education Program	40	UNKN
	Graduate programs in electrical engineering, computer sciences, naval architecture, applied physics, material sciences and mechanical and aerospace engineering	41	UNKN
	Military Graduate Education Program	1,024	25,000
	Summer Faculty Research Program	127	UNKN
Air Force/Army	Basic Research - Graduate Contract Research Programs	2,000	UNKN
Air Force	Graduate programs in thermionic engineering, composite structures, aircraft propulsion and manufacturing sciences	34	UNKN
Army	Graduate programs in computer science, electronics, modern optics, hypersonic aero-mechanics and aero-dynamics, and biogenetic engineering	35	UNKN
Army	Graduate Programs at Centers of Excellence in Rotary Wing Technology	17	2,300
Army	Summer Faculty Research Program	76	500
Army	ROTC - Science and Engineering Program	1,135	UNKN

research, as it has in 16 of the last 20 years, the result could be a return to a real decline in DOD investment in university research.

DOD basic research programs also support many graduate students as research assistants on university research projects. For example, a Navy study conducted in 1980 shows that the Office of Naval Research supports an estimated 2,200 graduate students (some fully, some partially) through its contract research program. It is conservatively estimated that the Army, Navy and Air Force support at least 4,000 graduate students on DOD-sponsored research projects.

The Army, Navy and Air Force also have begun graduate fellowship or specialized assistantship programs. In FY 83 more than 100 fellows are being supported in Defense-related disciplines under these programs. The Air Force has contracted with various industries and universities to create graduate education programs in thermionic engineering, composite structures, aircraft propulsion and manufacturing sciences. As of January 1983, 34 graduates students were enrolled in these programs. The Army has allocated funding for at least 25 fellowships in FY 83, an increase from 6 awards in FY 82. The Army's program includes fellowships in computer science, electronics, modern optics, hypersonic aero-mechanics and aerodynamics, and biogenetic engineering applicable to the production of enzymes. In addition, the Army has initiated in FY 83 Centers of Excellence in Rotary Wing Technology at three universities. These graduate programs will support 17 fellowships that will expand to 26 in future years. The Navy currently supports 41 graduate fellows in electrical engineering, computer sciences, naval architecture, applied physics, materials sciences and mechanical and aerospace engineering. Now in its second year, this program provides highly talented students with stipends of $12,500 and full tuition. The Navy is implementing its program with the help of the American Society for Engineering Education. It plans to

increase the funding of the fellowship program to $3 million by FY 85. These programs are individually tailored to each Service's needs and are aimed at obtaining specific critical sub-specialists in the future.

In FY 83 DOD started a University Research Instrumentation Program, which is jointly planned and funded at $30 million per year for 5 years by the Army Research Office, the Office of Naval Research and the Air Force Office of Scientific Research. In the first round of awards the DOD received almost 2,500 proposals requesting more than $645 million for equipment acquisitions. Included in DOD's FY 83 budget request of $828 million to Congress for the 6.1 research program was $30 million to support the instrumentation program. The $828 million 6.1 research budget request represented an increase of $132 million over the FY 82 budget of $696 million, or about 14% in real growth. Final Congressional appropriations, however, reduced the real growth increase in the 6.1 research budget from the requested 14% to 6.7%, of which 4.3% remained earmarked for the instrumentation program. With 4.3%, or almost two-thirds, of the increased earmarked for the instrumentation program, the net real growth in the FY 83 research budget was only 2.4% over FY 82. For this reason the Working Group recommends that new initiatives such as the DOD-University Research Instrumentation Program should be undertaken only in addition to sustained real growth in funding for the conduct of basic research.

Defense also has increased equipment buys in its contract programs from 4 percent of total contract research in FY 76 to about 10 percent in FY 82. Although these programs help to meet research equipment needs, the Department is not addressing the needs to rehabilitate university research laboratories in which DOD research is conducted, nor do present initiatives address the problems associated with obsolete and ineffective instructional equipment in these universities.

Universities also may benefit from a new DOD Independent Research and Development (IR&D) policy. IR&D in industry is supported through allowed overhead on DOD and NASA contracts. The purpose is to provide industrial contractors with funds to support exploratory research. A new policy, approved by the DOD IR&D Council in the fall of 1982, encourages Defense contractors to increase their interaction with universities by various means including research contracts, grants, faculty support and consulting, graduate student support, co-op and summer programs, research equipment sharing, and allowing staff participation as teachers or members of academic committees. However, new legislation is under consideration by Congress that would separate IR&D funds into separately identified accounts. If enacted, some believe the change would have an adverse impact on future funding for IR&D and so restrict use of these funds for universities.

Two other programs, rather limited in scope, should also be noted. A Summer Faculty Program at DOD laboratories provides summer research opportunities to more than 200 faculty members each summer. In addition, the Defense Authorization Act of 1982 provided authority for DOD laboratories to contract with educational and non-profit institutions for the research services of college and university students. Procedures to implement this program have since been developed and approved by the Defense Acquisition Regulatory Council for use by DOD laboratories.

IV. FINDINGS AND RECOMMENDATIONS

Introduction

The nation's universities are foremost among those institutions carrying out research in the United States and play a vital role in maintaining the country's economic and military strength. The universities are also the principal educational institutions for our future scientists and engineers, and research is a fundamental element of quality graduate education in science and engineering. Engaging in research as a part of the educational experience has expanded our knowledge, stimulated advances in the engineering and science curricula, and enabled the United States to assume world leadership both in performing research and in training research workers for industrial and government laboratories. Hence, a discussion of the issues surrounding the adequacy of quality education for the nation's future engineers and scientists cannot be conducted without recognizing the integral role which university research plays in the educational process. Education cannot be improved or enhanced unless the university research base is strong enough to support it. Consequently, maintaining a strong research program is essential to the growth and excellence of engineering and science education.

Beyond the research program, however, it has been noted that the problems facing the educational community are multiple and range from inadequate student preparation at the precollege level to faculty shortages and lack of up-to-date teaching and research equipment at the university level. These problems are jeopardizing the ability of the universities to provide the quality of education required to meet future industrial and defense needs. DOD also faces a range of related quality problems, primarily centering on the ability to recruit and retain high-quality S&E's for civilian and military positions. We have also found that numerous programs exist within the Department of Defense for addressing

a number of these problems. Some of these programs are limited in scope while others are broad-based and far-ranging.

Since the problems are multi-faceted, there must be a wide variety of programs and approaches put into place to deal with them. The Department is to be commended for beginning to respond at various levels to the many problems the secondary and higher education community is facing. However, while DOD has instituted a host of programs, there appears to be little coordination among these various efforts. The opportunity exists to make these individual efforts much stronger and more productive by providing a coordinated focus for them within the Department. At present, many of the programs managed by the personnel support community and designed to attract new civilian S&E's into DOD R&D installations are under-utilized by technical R&D managers either because they do not realize that these programs exist or because they are unsure how to take advantage of them. There is a need to improve the level of awareness, in the DOD R&D user community, of those programs designed for its benefit in recruiting and retaining qualified civilian S&E's.

Another example of under-utilization of existing authorities are those programs created to interest young people in careers in science and engineering within the Department. The potential exists for a young person to have work experiences within the Department from as early as 14 years of age through post-doctoral study via a variety of civil service appointment authorities. Yet, these opportunities are rarely linked together to provide young people with a continuum of employment and educational experiences. Co-op authorities, for example, authorize the Department to pay full tuition, room and board, and book expenses for co-op students who work in DOD laboratories while attending college. Yet, this scholarship program is little utilized.

Another role which the Department must assume is that of advocate for strengthening engineering and science education. The Working Group recognizes that DOD is not the Department of Education, and that any programs recommended for Defense implementation in response to needs in science and engineering education must focus on the Defense mission and not on a general education mission. Nonetheless, DOD should be a more visible and vocal advocate, both within and outside the Administration, for quality science and engineering education.

Keeping in mind these comments on the relationship of research and education, and the need for greater coordination and advocacy, the Working Group believes that as a matter of policy, DOD has the responsibility to:

1. Work cooperatively with other federal agencies, state and local governments and the private sector to address national needs in engineering and science education.

2. Focus on needs and capabilities unique to DOD in order to assure a sufficient supply of highly qualified individuals in key Defense related fields.

3. Develop mutually beneficial programs with the universities that will enhance long-term relationships, being careful not to exacerbate the difficult problems our universities now face.

The Government, it is recognized, cannot compete monetarily in the market place for top scientific and engineering talent. Reasonable pay comparability, coupled with other rewards, is necessary in order to keep competent people in the military services and the civil service. Some of these rewards include stability of employment and an assured pension system. For scientific and engineering personnel additional incentives include the nature of the work in which they are engaged, the positive reputation of their organization (lab,

test center, etc.), access to state-of-the-art equipment and technology, proximity to universities and opportunities for continuing education and professional growth. When shortages of critical skills develop, industry can be expected to win in a salary bidding war for the most highly capable personnel. Thus, policies and programs must be in place which will attempt to retain a reasonable number of these people by using incentives other than pay alone. Where these incentives are not sufficient to retain our top personnel, then the policies and programs in place should at least assure a continuing flow of capable people at various skill and experience levels who are able to replace those lost to industry or academia. In fact, some turnover in personnel is recognized as healthy and conducive to new ideas, approaches and energy levels needed to keep an organization current and capable.

Many of the needed policies and programs are already in place. Some require expansion, others a renewed emphasis. Simple legislative changes will improve the effectiveness of some existing programs. One major new program is recommended in order to fill a need in the process of providing highly skilled, graduate S&E personnel. It is suggested that this initiative, here titled the Defense Civilian Graduate Scholarship Program, can fill an extremely important need by providing a regular supply of top quality, high-technology S&E personnel with advanced degrees to the DOD civilian workforce.

Findings

1. Shortages of both civilian and military S&E personnel exist within the Defense Department (approximately 4,000 civilians based on current vacancy rates in DOD laboratories and a projected shortfall of 6,000 military officers by 1987) and are reasonably documented and understood. The qualitative aspects of the problem, however, are not as well defined.

2. ROTC scholarship programs are highly competitive and are providing an increasing quantity of high quality new S&E officers having four-year service commitments.

3. Civilian hires of new baccalaureate S&E personnel at GS-5/7 levels, although currently sufficient in quantity, do not appear to match the quality level of the ROTC graduates.

4. The bonus program recently implemented by the Air Force to retain experienced, mid-grade (O-4/5) officers having between 4 and 12 years of service, appears to be achieving desired results.

5. Over half (58%) of the civilian S&E personnel being lost from DOD laboratories are leaving at the journeyman level (GS-12/13). These include a small but significant number of exceptionally well qualified people.

6. Work-related civilian programs such as cooperative education and summer internships have been shown to have a high rate of conversion to full-time civil service employment and retention after the conversion.

7. DOD has not taken full advantage of continuing education opportunities provided by legislative authorities to send current, full-time civilian personnel to graduate programs.

8. Although the occupation of computer professional is a recognized critical shortage area, the government occupational classifications do not properly identify computer skills. On the military side of the Army and Air Force, neither

computer scientists nor computer engineers can be identified or assigned. In the civil service side and on the military side of the Navy, a computer science classification exists, but not one for computer engineer. As a result, it is not possible to identify requirements, match the supply, and provide for proper hiring, assignment or career planning in these crucial fields.

9. The quality of precollege math and science has been eroding and the number of high school students enrolling in these courses has decreased.

10. Serious shortages now exist in the number of qualified math and science teachers at the high school level, and there has been a general decline in the quality of those who are teaching at this level.

11. Adverse pay differentials are pulling high-caliber graduate students and faculty into industry, creating a shortage of quality new engineering Ph.D.'s in many universities.

12. Research facilities and equipment deficiencies pose perhaps the most serious long-term problem for universities. Research instrumentation has grown more sophisticated and research costs have risen sharply while there has been a severe erosion in the condition of many university research laboratories. As a result, quality research efforts have shifted to a limited number of superior laboratories.

13. The Army, Navy and Air Force have begun graduate fellowship and specialized assistantship programs in support of Defense related disciplines.

14. This year DOD is starting a University Research Instrumentation Program which is jointly planned and funded (at $30 million per year for five years) by the Army Research Office, the Office of Naval Research and the Air Force Office of Scientific Research.

15. A new Independent Research and Development (IR&D) policy has been initiated by DOD (supported through allowed overhead on DOD and NASA contracts) which enables industrial contractors to support university research.

16. DOD laboratories are providing summer research opportunities to a limited number of university faculty through a Summer Faculty Program.

Recommendations

The Working Group on Engineering and Science Education offers the following recommendations to the DOD-University Forum:

Recommendation I

Continue Policies of Support for University Research.

DOD should support a policy of sustained real growth in funding to support the conduct of basic research in the universities over the next decade. The Working Group endorses the current Secretary of Defense Budget Guidance (FY 85-89) which would provide for a 7% annual real growth in university research over the next five years, and believes this should be viewed as the minimum growth rate necessary to sustain a productive research enterprise. The new initiatives recommended below should be funded with new appropriations and not *at the expense of the* sustained real growth required in the research programs.

Recommendation II

Undertake a Special Study to Define and Assess Those Factors Which are Contributing to the Perceived Erosion in the Quality of the DOD Engineering and Scientific Workforce.

Numerous studies have been undertaken to define the quantitative imbalances in the supply and demand of S&E's. However, the specific dimensions of the qualitative problem are relatively unknown. Considerable concern exists throughout the DOD R&D community over significant losses of high-quality experienced S&E personnel. There are additional concerns over the perceived decline in the quality of the pool of new engineering graduates and those the DOD is able to hire into its workforce

Recommendation III

Establish a Focal Point for S&E Education in OSD.

A stronger and more clearly identified focal point for engineering and science education policy and programs should be established within the Office of the Secretary. An organization should be charged with primary responsibility for developing and coordinating S&E education and training policy Department-wide, particularly among the Services, in all areas of engineering and science education and training. It should:

- develop more effective linkages and cooperative relationships with other federal agencies (particularly the National Science Foundation), national organizations, state and local governments and the private sector to address national needs in engineering and science education.
- develop clear, effective and consistent goals, policies, program objectives and procedures for all DOD engineering and science education and training programs.
- coordinate the development of education and training initiatives among the Services, consistent with DOD needs, goals and objectives.
- assess on a continuing basis DOD requirements for engineering and science education, for both military and civilian personnel, and formulate effective approaches to meet them.
- establish improved working relationships between DOD research, personnel and training offices, on the one hand, and university education and advanced training programs on the other.
- develop effective incentives to encourage greater participation by military and civilian personnel in DOD continuing education programs.
- identify policy and program barriers preventing better utilization of continuing education programs by DOD military and civilian personnel; formulate ways to remove them.

- improve working relationships between the Department and universities as they concern the development of continuing education and faculty development programs appropriate to the Department's needs.

Recommendation IV

Continue and Strengthen Military Undergraduate and Graduate Level S&E Education and Bonus Programs.

a. Continue support for the ROTC scholarship programs and the military graduate level S&E education programs at the Air Force Institute of Technology and Naval Postgraduate School.

b. Strengthen the DOD-university linkage in graduate programs through better utilization of colleges and universities. Such steps will strengthen the variety of sources for advanced degree officers, as well as further the effort to increase the overall quality of these officers.

c. Recommend that Army and Navy examine Air Force experience with bonus programs with a view to considering appropriate initiatives in their own Services.

d. Establish computer science occupational/skill codes for military personnel in the Army and Air Force, and computer engineering occupational/skill codes for all the Military Services and for the civil service. These codes will allow better management of computer professional skills, and permit the establishment of bonus programs in all three Services for computer engineers.

Recommendation V

Continue and Expand Civilian Precollege, Undergraduate and Graduate Level Assistance Programs.

a. Expand size of and support for precollege and undergraduate work experience programs, *e.g., apprenticeship*, co-op and intern programs, and develop linkages among them to provide a continous series of work experiences for young people within DOD installations. Adjust policies and regulations (and request

changes in legislation if needed) to remove disincentives that presently discourage managers from using these programs (such as civilian employment ceilings) and to assure that fair, enforceable commitments exist for service after graduation. Fully utilize recently issued Defense Acquisition Regulatory Council regulations (implementing authority is provided by Sec. 603, Title VI, 1982 DOD Authorization Act) to enable DOD laboratories to contract for the research services of students, thereby providing additional work experience opportunities for S&E students in DOD facilities.

b. The perceived need for an undergraduate prepaid GI bill or "ROTC-like" civilian program can best be met by increased utilization of the co-op program, including greater use of its provisions for scholarship support.[1] Current legislation authorizes financial support to students in their junior and senior years in trade for employment commitments. Since this program utilizes existing authorities, does not require additional legislation, and does not conflict with ROTC programs, the Working Group believes it should be expanded before a new undergraduate program is implemented.

c. Undertake planning for the establishment of a new graduate education program for civilians -- not limited to current employees -- that will provide scholarships for experienced S&E personnel for the purpose of obtaining an advanced S&E degree either at the masters or Ph.D. level. This program, which could be entitled the Defense Civilian Graduate Scholarship Program, will require Congressional approval, new legislation, new budgetary authority and management implementation. It is intended that such a program should have national stature and be designed to attract quality candidates, principally from the private sector, with commitments to assure that they stay in DOD S&E positions for a stated period. Furthermore, the program should include an explicit provision

1/This addresses the tasking given by Dr. DeLauer which was cited on p. 2.

for the replacement of those highly experienced employees at mid-grade (GS-12/13) currently being lost to industry and academia. DOD should take immediate steps to develop program details and request Congressional approval at the earliest date. A high-level working group within DOD should be formed immediately in order to develop such a program.

d. Request OPM to identify a separate occupational skill code for civilians who are qualified and working as computer engineers (similar to the recommendations above for military personnel). This will allow better identification of requirements for this skill and will improve career management of these personnel. Also, request OPM to approve higher pay scales for computer science applicants approximating those for engineers. This will give more competitive recruiting opportunities in this shortage skill.

Recommendation VI

Increase Opportunities for Continuing Education for Civilian S&E's Now Employed by the Department.

Emphasize and use currently available continuing education opportunities for experienced civilian employees. Reduce administrative barriers and strengthen management support. Participation goals should be set and funds should be assured. The best qualified personnel should be encouraged to take advantage of advanced educational opportunities. The working group called for in Recommendation V(c) above should carefully review the administrative and legal limitations to these programs, including the following:

(1) Legislation does not allow selection of personnel for advanced schooling for the purpose of obtaining a degree. Nevertheless, a degree is the accepted proxy for a level of knowledge, and supervisors want to hire or assign persons who have earned advanced degrees. The law and personnel procedures, or both, should be changed to allow competitive selection of individuals for entrance into fully paid degree programs without resorting to well known "workarounds" that impose long-run handicaps on effective programs.

(2) Current legislation limits long-term training to 12 months duration (out of 10 years). Although this restriction may allow the completion of a few S&E master's programs, the restriction has the effect of precluding most two-year master's programs or any sort of doctoral education since they simply cannot be completed in one 12-month period in a 10-year span. Current law and procedures, or both, should be changed to permit waivers of this rigid limitation when good reasons exist.1/

(3) The whole area of commitments in repayment for education should be examined. If a lab director selects and sends a valuable staff member to school in a specific specialty, the director should be able to plan with some confidence on this individual's availability for an appropriate payback period. Currently, an individual only has a moral responsibility to stay in the sponsoring organization and is legally free to transfer to a new or completely unrelated government position (in another agency, for example). Further, if the individual leaves government service, the only payback required is the direct cost of the schooling received and not salary or any of the indirect expenses which were covered in connection with his/her schooling.

(4) Internal management policies and practices need to be changed to assure individuals leaving their jobs for advanced schooling that their career opportunties are not adversely effected by their absence. Many S&E employees in DOD laboratories indicated that their career would be jeopardized by going away to school. The reward system seems to place greater value on mere presence in the workplace than on education to improve professional potential. In addition, employees absent to attend full-time schooling should not be counted against agency manpower ceilings, and means should be developed to provide for temporary manning during the period that these employees are away.

1/Agency heads, including the Secretaries of the Military Departments, currently can approve, on a person-by-person case, a two-year schooling absence. Guidance on use of this authority is contained in DODI 1430.5.

Recommendation VII

Increase Interchanges Between Senior Government S&E Personnel and Colleagues in Industry and Academia.

Encourage increased interchanges and contacts between senior government S&E personnel (military and civilian) with colleagues in industry and academia. Membership in professional associations, attendance at symposia, conferences, seminars, short courses, and the presentation of appropriate research papers are essential. Defense managers ought to review the quality and currency of senior scientists and engineers. Because this group has the burden of leadership and management of Defense programs, time or opportunities may not be taken for the activities necessary to assure currency and continual upgrading in their respective fields. Formal programs for the summer hire of university faculty should be expanded and strengthened in areas of interest to DOD so as to provide further contact between government S&E's and academia.

Recommendation VIII

Strengthen DOD Graduate Fellowship Programs.

The Department of the Navy has begun a small Ph.D. graduate fellowship program designed to attract a limited number (about 45 per year) of talented undergraduate students into advanced academic training in key fields of engineering and science. This program emphasizes quality, and is intented to contribute to the flow of exceptional young minds into disciplines which are essential to our research and technological development. This program offers full tuition plus stipends of $12,500 and is thus able to compete more effectively in the marketplace than other federal graduate awards.

The present initiative is an excellent first step, but should be expanded. The Working Group joins with the House Armed Services Committee in recommending that

"[t]his program should be expanded by the Navy, and the approach should be adopted by the Army and Air Force."[1/] To this end the Group recommends that necessary legislative authorization be sought to expand the program to involve all the Services, and to allow for approximately 300 3-year awards per year, divided among the Army, Navy and Air Force.[2/] At steady state the Army, Navy and Air Force would each budget approximately $6 million per year to sustain the program -- a small investment to help ensure excellence in these critical fields.

Beyond the program just described, consideration should be given to developing and funding a program which would award an equivalent sum ($6 million) to support graduate fellows in university departments conducting research for DOD. These funds would be allocated based on the proportion of Defense related research conducted by these university departments, and awarded to eligible students by department chairmen.

Together these two programs would provide a balanced and effective graduate fellowship program to help ensure a continual flow of quality graduate students through academic departments engaged in DOD-funded fundamental research.

<u>Recommendation IX</u>

<u>Establish a Comprehensive Faculty Development Program</u>.

The Department has a number of initiatives designed to foster interest among faculty in DOD research needs. At the level of individual laboratories a variety of ad hoc arrangements exist to inform faculty about research opportunities and to give faculty first-hand experience working with DOD research personnel. The Group recommends that the Department formulate clear policies and programs to foster faculty development and interest in research careers in disciplines important to the Department. This activity would appropriately fall to the OSD

1/HASC Report 97-107, pp. 137-138.

2/The SASC and the HASC have both urged DOD to strengthen its budgetary requests in order to finance graduate fellowship initiatives. See SASC Report 97-330 and HASC Report 98-107.

focal point discussed in Recommendation III. A variety of mechanisms are suitable and effective, including faculty exchange agreements and summer appointments in DOD laboratories -- an approach now used with some success.

In addition, the Department should address the need to help ensure a continuing flow of young faculty into certain key fields, particularly engineering. This would require a new program of career-initiation awards to attract new talent into faculty research careers. Awards to universities tailored to the needs of particular disciplines and sustained for a period of 5 years, very much like the new NSF Presidential Young Investigators Awards program, would assist institutions in attracting talented individuals into faculty careers. Awards should allow for flexibility to permit institutions to fit awards to the requirements and resources of individual departments in which DOD research programs are conducted. We recommend that a total of 50 5-year awards be made each year at an average annual cost of $50,000 per award. This will require an expenditure of $2.5 million in the first year and will reach an annual total of $12.5 million when fully funded.

Recommendation X

Encourage the Development of University Programs in Defense Related Technologies.

A standing committee of DOD and university representatives should be established to encourage the development of academic programs in universities in response to specific Defense needs. Of particular urgency are programs leading to centers of excellence in manufacturing technology, quality control, and the improvement of reliability and maintainability. This should be a university-based initiative, with DOD help, that will provide improved capabilities in these technologies together with faculty and graduate programs to provide a reservoir of expertise in these essential technologies.

Recommendation XI

Strengthen the DOD-University Research Instrumentation Program. 1/

The Working Group recommends that the DOD-University Research Instrumentation Program be expanded to a level of $100 million per year, and that it be sustained at that level for at least 5 years. New funds should be requested for this purpose. All awards should continue to be decided by national competition and judged according to an institution's capacity to conduct research and related educational activities at the highest levels of undergraduate education.

The newly initiated $30 million program to upgrade university research instrumentation has illuminated the deteriorated condition of many of the university research laboratories in which DOD-funded research programs are carried out. In its first year the program received more than 2,500 proposals requesting more than $645 million. Only 200 proposals, fewer than 1 in 12, could be funded. Clearly the program has touched a pressing need lying at the heart of the research establishment. At this funding level, however, the program is falling far short of meeting the needs of the DOD research base.

Recommendation XII

Establish a Research Facilities Rehabilitation Program. 2/

The Department should undertake a targeted research laboratory rehabilitation program to assist universities in the task of modernizing essential, but outdated, research facilities. A carefully constructed program of matching grants targeted on the modernization of those laboratories in which DOD-funded research programs are housed is warranted and necessary if these laboratories are to be suitable sites for DOD fundamental research activities through the rest of the decade and into the 1990's. This "brick and mortar" program would begin to address a

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1/SASC and HASC Reports which support this recommendation are included in Appendix D.

2/Ibid.

substantial national problem, one that is already impacting adversely on the capabilities of university research and training programs in general, including productivity of DOD-funded research programs.

Specifically, we recommend that DOD undertake a long-term initiative, funded at a level of $100 million per year for 10 years, to upgrade or replace selected university research laboratories that are essential to DOD research programs. Awards, made on a matching basis with university, state and/or industry funds, should be made competitively among those institutions that possess the demonstrated capacity to make substantial contributions to our knowledge in those fields which are essential to our long-range national security. As in the instrumentation program proposed above, the emphasis of this targeted facilities renewal program should be on selectivity and excellence in fields directly related to the needs of the Department's long term mission -- not on the creation of wholly new research capabilities.

APPENDIX A

Membership of the Forum

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Membership of the Forum

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APPENDIX C

Support to the Working Group

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Support to the Working Group

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APPENDIX D

Reports of House and Senate Committees on Armed Services

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Reports of House and Senate Committees on Armed Services

House Armed Services Committee Report 97-71, Part I, 97th Congrss, 1st Session; DOD Authorization Act, 1982; pp. 78-79, "Technology Resources."

House Armed Services Committee Report 97-482, 97th Congress, 2nd Session; DOD Authorization Act, 1983; pp. 197-198, "Shortage of Engineers."

House Armed Services Committee Report 98-107, 98th Congress, 1st Session; DOD Authorization Act, 1984; pp. 137-138, "The Science and Technology Resource Base."

Senate Armed Services Committee Report 97-330, 97th Congress, 2nd Session; DOD Authorization Act, 1983; pp. 105-106, "Defense Agencies Research and Development."

97TH CONGRESS } HOUSE OF REPRESENTATIVES { REPT. 97-71
1st Session } { Part I

DEPARTMENT OF DEFENSE AUTHORIZATION ACT, 1982

MAY 19, 1981.—Ordered to be printed

Mr. PRICE, from the Committee on Armed Services, submitted the following

REPORT

together with

DISSENTING, INDIVIDUAL, AND ADDITIONAL VIEWS

[To accompany H.R. 3519]

TECHNOLOGY RESOURCES

During the 96th Congress, the committee examined the state of the nation's industrial capacity. One of the glaring inadequacies uncovered by the committee and highlighted in its report titled: "The Ailing Defense Industrial Base: Unready for Crisis," was the lack of adequate trained technical manpower and facilities for our national defenses.

Testimony before the Subcommittee on Research and Development indicates that the nation's investment in research, in general, and in the university research base of manpower, instrumentation and facilities, in particular, is eroding. During the period 1968–1980:

R&D as a percentage of the Federal budget decreased 36 percent.

R&D expenditures as a percentage of GNP decreased 19 perment, while it has gone up 14 percent in the Soviet Union, 16 percent in West Germany and 19 percent in Japan.

Scientists and engineers engaged in R&D as a percentage of the labor force declined 9 percent; that percentage increased 62 percent in the Soviet Union, 75 percent in West Germany and 70 percent in Japan.

Many research laboratories at our leading universities are old, and universities are unable to sustain investments adequate to keep them up to date. Recent studies by the Association of American Universities found that the median age of research instrumentation in universities now is twice that of leading commercial laboratories. Research productivity and instruction are being compromised. Many laboratories also are in need of a major overhaul. In 15 leading universities it is estimated that over the next three years, facility rehabilitation needs will exceed $1 bilion, or over 250 percent of the combined expenditures made for these purposes in the previous four years.

The country faces a growing shortage of Ph. D. level scientists, engineers and foreign language and area studies specialists. The nation's schools of engineering report 2,000 unfilled faculty vacancies. Comparable shortages exist in many language specialties, some of the natural sciences and the computer sciences. For example, Ph. D. graduates in computer sciences declined from 256 in 1975 to only 200 in 1980, which 1,300 were needed to fill national needs. In contrast, the

Soviet Union, West Germany and Japan have steadily increased their production of scientists and engineers. As an example, the Soviets graduated just under 300,000 engineers last year; the U.S. graduated 50,000. The United States has fallen further behind, especially in crucial defense-related fields such as electrical engineering, chemical engineering and computer sciences.

In the case of university laboratories that carry out significant Department of Defense research, the committee believes that the Department of Defense should consider what part the Department of Defense can play in the effort to rehabilitate the university research base. The feasibility of using graduate fellowships in defense-related fields, including area studies, as a method to ultimately bolster the critical defense skilled manpower pool should be considered. Such awards could provide incentives for students to pursue graduate studies in areas critical to our national security needs.

The committee believes a study, similar in nature to the excellent report of the Defense Science Board Task Force on Industrial Responsiveness, should be undertaken on university responsiveness to national security requirements. The committee would like to have the study provided to it prior to submission of the fiscal year 1983 authorization request.

(78-79)

97TH CONGRESS
2d Session

HOUSE OF REPRESENTATIVES

REPORT No.
97-482

DEPARTMENT OF DEFENSE AUTHORIZATION ACT, 1983

REPORT

OF THE

COMMITTEE ON ARMED SERVICES

together with

INDIVIDUAL, ADDITIONAL, AND DISSENTING VIEWS

ON H.R. 6030

[Including cost estimate of the Congressional Budget Office]

APRIL 13, 1982.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

U.S. GOVERNMENT PRINTING OFFICE
92-585 WASHINGTON : 1982

SHORTAGE OF ENGINEERS

Critical shortages in a variety of skills continue to plague the military. Last year the committee expressed its concern about engineering shortfalls in the services and the lack of attention paid to officer professional development education by the Department of Defense. In response, the committee recommended and the Congress passed a continuation bonus for military engineers in critical specialities.

Current engineering shortages will likely become more severe in the next twenty years for several reasons. First, engineering requirements for both industry and government are likely to increase significantly as technology continues to spread thoughout the private and public sectors. Second, while computers and weapons systems are becoming more complex and demanding, the pool of new engineers will be shrinking in various critical areas. This will occur as a result of a decline in the birth rate, the reportedly deteriorating quality of U.S. technical education at the university and secondary school levels, and an imbalance among engineering specialties. Third, the United States could find itself in the same situation as in the early *1970's—too* many engineers of one type and not enough of another.

Compounding the national problem, the military will be particularly hard pressed to attract and retain engineers because of the discrepancies in salaries between those employed by the government and those in the private sector. A further problem is that premium starting salaries for newly graduated science and engineering students discourage these individuals from seeking advanced degrees. Only 15 percent of the top engineering graduates today enroll in graduate programs. Similarly, many among university faculty in engineering are leaving adademia for jobs in industry for salaries that are sometime double university pay. Approximately 2,000 engineering and 200 computer science faculty positions are currently unfilled nationwide. These two factors could lead to a shortage of faculty to train future engineers.

Greater engineering shortfalls in the future will likely harm the U.S. defense posture. In contrast, the Soviet Union graduated nearly five times as many engineering students in 1979 as the United States.

The Air Force has been the most concerned of the services about shortages of engineers. In fact, Air Force personnel managers have been aggressively pursuing measures to relieve shortfalls for the last two years. The Army, the Navy, and the Marine Corps apparently have not been as concerned about the problem. The committee believes that each service should examine all possible avenues to encourage the recruiting and retention of the engineers required to sustain the national defense program, as well as the nation's defense industrial base, in years to come.

98TH CONGRESS 1st Session | HOUSE OF REPRESENTATIVES | REPORT No. 98-107

DEPARTMENT OF DEFENSE AUTHORIZATION ACT, 1984

REPORT

OF THE

COMMITTEE ON ARMED SERVICES

together with

INDIVIDUAL, ADDITIONAL, AND DISSENTING VIEWS

ON H.R. 2969

[Including cost estimate of the Congressional Budget Office]

May 11, 1983.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Committee recommendation

The committee recommends authorization of $30 million for the second year of the University Research Equipment program. The committee also directs that a study be undertaken by the Secretary of Defense on the need to modernize university science laboratories essential to long-term national security needs. The study should be submitted to the committee by March 15, 1984.

Basis for committee action

During the 97th Congress, the committee examined the nation's deteriorating university research and education base. It found an eroding capacity to conduct research and advanced education programs in fields of science and engineering essential to the national defense. The committee provided authorization of $30 million in fiscal year 1983, and with the assistance of the Department of Defense, university reseach programs were strengthened. A new university research equipment program and a new graduate fellowship program were established.

Many of the university research laboratories in which Department of Defense research programs are conducted are obsolete and in need of major modernization or replacement. The committee believes a study should be undertaken on the need to modernize university laboratories in the physical sciences, earth and ocean sciences, atmospheric sciences, engineering, computer sciences and other fields essential to our long-term national security. The survey should (1) document the laboratory needs of universities presently engaged in Department of Defense competitive research programs, (2) assess priorities by academic field, (3) provide estimates of costs to meet these needs, (4) provide specific recommendations appropriate to the Department of Defense and others designed to address the need (5) state the consequences to our long-term national security.

The committee is advised that, although important progress has been made, very serious problems remain to be addressed. The response to the first year of competition for the university research equipment program illustrates the serious needs of our research base. More than 2500 proposals were received requesting over $645 million. Only 200 awards could be made, funding fewer than 1 in 12 proposals. Many worthwhile proposals had to be rejected because of funding constraints.

The committee recommends authorization of $30 million for the second year of this important program and requests the Department of Defense to substantially strengthen it in the fiscal year 1985 budget request. The new graduate fellowship initiatives, particularly those developed by the Navy, will help to greatly reduce the shortage of Ph. D. level scientists and engineers in critical defense-related fields. This program should be expanded by the Navy, and the approach should be adopted by the Army and Air Force.

Calendar No. 475

97TH CONGRESS 2d Session	SENATE	REPORT No. 97–330

DEPARTMENT OF DEFENSE AUTHORIZATION FOR APPROPRIATIONS FOR FISCAL YEAR 1983 AND SUPPLEMENTAL AUTHORIZATION FOR APPROPRIATIONS FOR FISCAL YEAR 1982

REPORT

[To accompany S. 2248]

ON

AUTHORIZING APPROPRIATIONS FOR FISCAL YEAR 1983 FOR PROCUREMENT, FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION, AND FOR OPERATION AND MAINTENANCE FOR THE ARMED FORCES, TO PRESCRIBE PERSONNEL STRENGTHS FOR THE ARMED FORCES AND FOR CIVILIAN PERSONNEL OF THE DEPARTMENT OF DEFENSE, AND FOR OTHER PURPOSES

together with

ADDITIONAL VIEWS

COMMITTEE ON ARMED SERVICES
UNITED STATES SENATE

APRIL 13, 1982—Ordered to be printed

U.S. GOVERNMENT PRINTING OFFICE
91-881 O WASHINGTON : 1982

Senate Report No. 97-330
105 - 106

DEFENSE AGENCIES RESEARCH AND DEVELOPMENT

Recommended for Approval as Requested

Defense Department University Research Support

The committee has examined the recent report of the Defense Science Board Task Force on University Responsiveness to National Security Requirements and other evidence documenting the deteriorating health of the Nation's research universities. The committee is concerned that our leading research universities are suffering from a severe erosion in their capacity to conduct competitive research and advanced education programs in such key fields as science and engineering. Manifestations of such erosion may be found in the fact that many laboratories and much research equipment is seriously outdated. Moreover, insufficient numbers of talented students and researchers are being attracted to careers in fields of science and engineering essential to the Nation's future security. In short, the university research base in the United States is being dramatically weakened with grave implications for the national security.

Consequently, the committee fully supports the proposed expansion of the Department's university research programs, the new research instrumentation program, the graduate fellowship program and other related steps planned by the Department, which have been incorporated in the fiscal year 1983 budget request. The committee urges the Department further to strengthen these important programs in its submission of the fiscal year 1984 authorization request.

The committee also requests that the Department of Defense provide an assessment of the degree to which the national defense requires a vigorous program for providing education and training in foreign languages and area studies. This assessment should include recommendations as to measures, and their costs, which could be implemented to rectify the deficiencies that currently exist in these fields.